OptiWater

optiDesigner ver. 1

User Manual

October 2001

Contents

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Introduction

What is optiDesigner

optiDesigner is a Windows software for the optimal design of water distribution networks using "**Genetic Algorithms**" (see bellow). The program uses EPANET (a hydraulic simulator distributed by the US EPA) for the drawing and analyzing the system. **optiDesigner will design the network pipes and find their minimal cost under a set of constraints,** which includes:

- Minimal and maximal pressures at networks nodes.
- Minimal and maximal velocities at networks pipes.
- Maximal sources flow.

With optiDesigner you can find the most cost effective design, rehabilitation and expansion of your water distribution system.

But, if you are looking for a software that, on a push of a button, will design a water distribution system with no engineering work done by you, optiDesigner is not for you. optiDesigner can not replace the engineer; it could only help him! Every piece of data that you enter into the model should be considered carefully since the algorithm can not think for you. What it does, is only search (of course in a smart way) the vast space of design possibilities.

Having said that we are ready to proceed with optiDesigner.

What are Genetic Algorithms?

Genetic algorithms were invented by Holland to mimic some of the processes of natural evolution and selection. In nature, each species needs to adapt to a complicated and changing environment in order to maximize the likelihood of its survival. The knowledge that each species gains is encoded in its chromosomes, which undergo

transformations when reproduction occurs. Over a period of time, these changes to the chromosomes give rise to species that are more likely to survive, and so have a greater chance of passing their improved characteristics on to future generations. Of course, not all changes will be beneficial but those that are not tend to die out.

Holland's genetic algorithm attempts to simulate nature's genetic algorithm in the following manner. The first step is to represent a legal solution to the problem you are solving by a string of *genes* that can take on some value from a specified finite range or alphabet. This string of genes, which represents a solution, is known as a *chromosome*. Then an initial population of legal chromosomes is constructed at random. At each generation, the fitness of each chromosome in the population is measured. The fitter chromosomes are then selected to produce offspring for the next generation, which inherit the best characteristics of both the parents. After many generations of selection for the fitter chromosomes, the result is hopefully a population that is substantially fitter than the original.

Steps in using optiDesigner

The following steps are to be taken for the use of optiDesigner:

1. Draw the system using EPANET and set systems properties.
2. Export the network from EPANET as an INP file.
3. Start a new project within optiDesigner and select the INP file.
4. Define the design options.
5. Set the pipes to be designed.
6. Set constraints.
7. Set optimization parameters.
8. Run the simulation.
9. View results using EPANET.

Quick start

Installing optiDesigner

optiDesigner is designed to run under the Windows 95 (and higher) operating system. It is distributed as a single file, **optiDesigner1.exe**, which contains a self-extracting setup program. To install optiDesigner:

1. Select **Run** from the Windows Start menu.
2. Enter the full path and name of the **optiDesigner1.exe** file.
3. Click the **OK** button type to begin the setup process.
4. Follow the instructions of the setup program.

Should you wish to remove **optiDesigner** from your computer, you can use the **Add/Remove** option in the **Control Panel** (Be sure to read the registration matters in this manual before removing **optiDesigner**.

Hardware and Software requirements

Hardware

In general, **optiDesigner** needs as much computer power as you can supply. **optiDesigner** was tested on machines with at least 128MB RAM and 750MHz Pentium III processor. The software can be used on machines with less memory and slower processors but it will reflect on the software performance (run time).

The optimization process may take minutes and even more then an hour depends on the system being designed. The more RAM and processor power you have, the optimization process will take less time.

Software

Beside the software it self, you will need a copy of EPANET Ver. 2.00.08 or version

2.00.09. It can be downloaded freely from the following site:

http://www.epa.gov/ORD/NRMRL/WSWRD/epanet.html

Example tutorial

In this chapter we will solve a simple optimization problem taken from:

"Design of optimal water distribution systems" by E. Alperovits and U. Shamir, 1977.

The network file (INP file) is located in the "Tutorial" sub-directory in the directory you installed optiDesigner in (by default: C:\PROGRAM FILES\OPTIDESIGNER).

Consider the network in the "**tutorial.inp**" file, which has eight pipes of 1000 meters length each, arranged in two loops and is fed by gravity from a constant head reservoir. The demands are given in the data table below and the head at each node is to be at least 30 meters above the ground elevation of the node. The pipe costs, per unit length, are given in the table below. Chw is 130 for all pipes.

Nodes data:

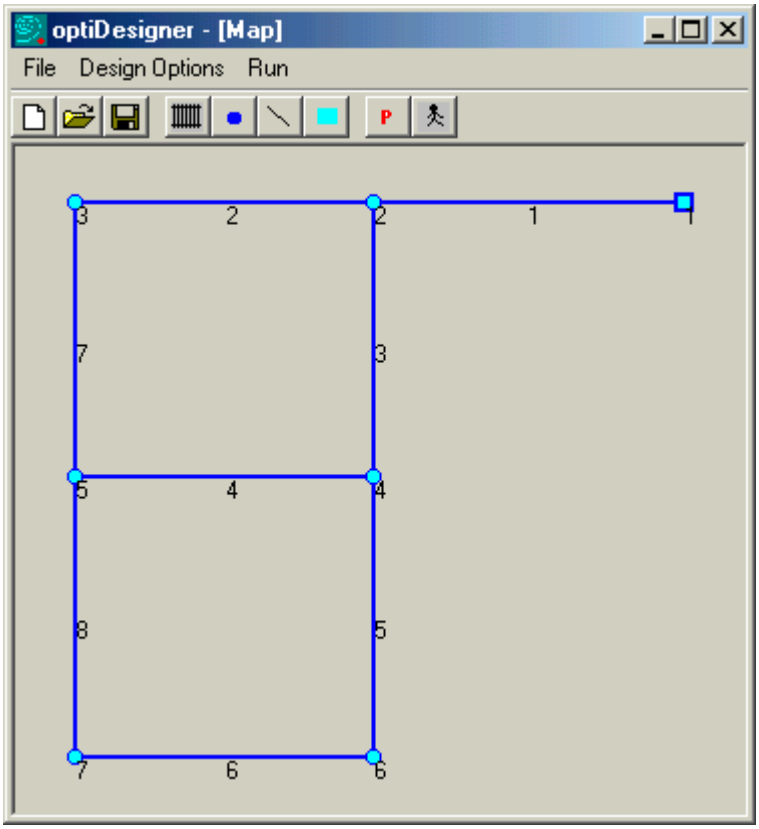
Node	Demand (CMH)	Elevation (m)
1	-1120	210
2	100	150
3	100	160
4	120	155
5	270	150
6	330	165
7	200	160

Pipes costs:

Diameters (")	Unit cost
1	2
2	5
3	8
4	11
6	16
8	23
10	32
12	50
14	60
16	90
18	130
20	170
22	300
24	550

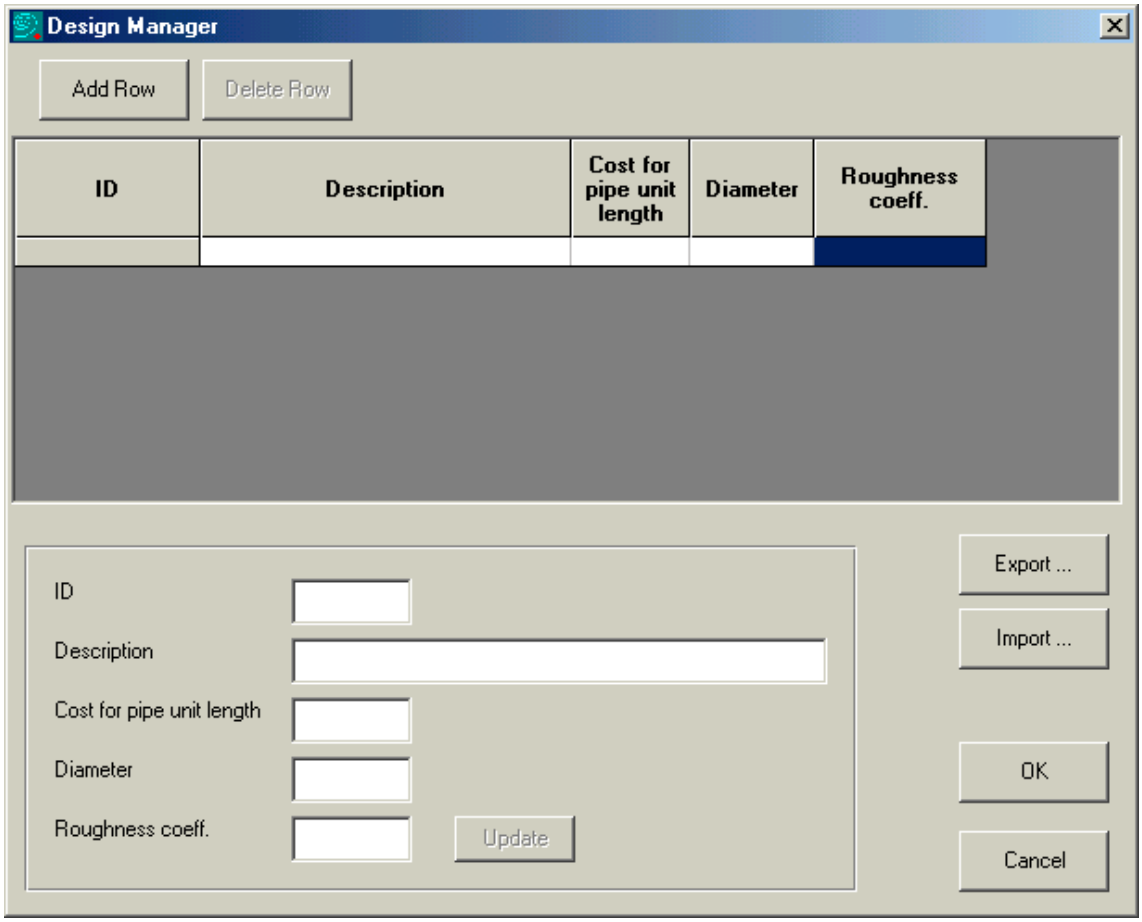
To solve this problem start optiDesigner and:

1. Select "**New**" from the "**File**" menu and chose the "**Tutorial.inp**" file.
2. You will see the following screen:

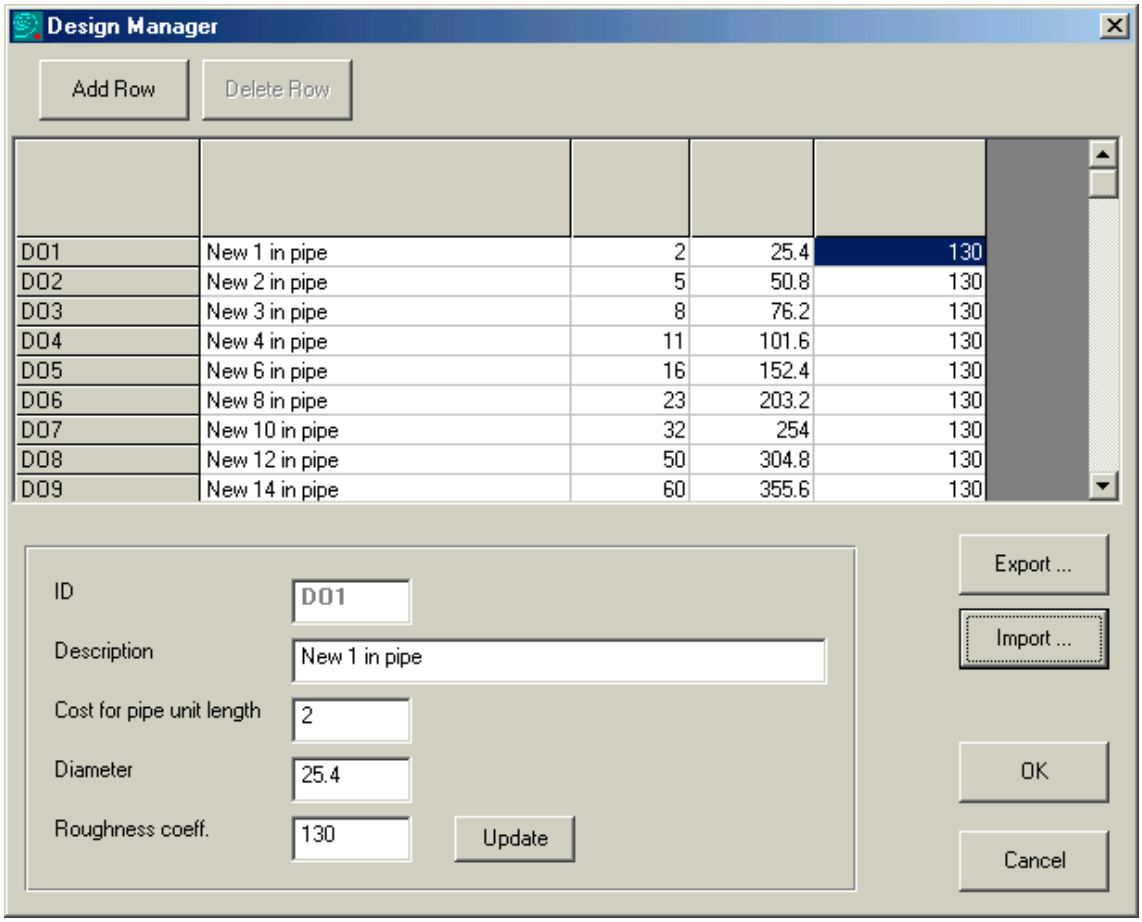


3. To save the design project click the "**Save**" option from the "**File**" menu and give the project a name ("**Tutorial.od**").

4. To enter the design options select "**Design Manager**" from the "**Design Option**" menu:

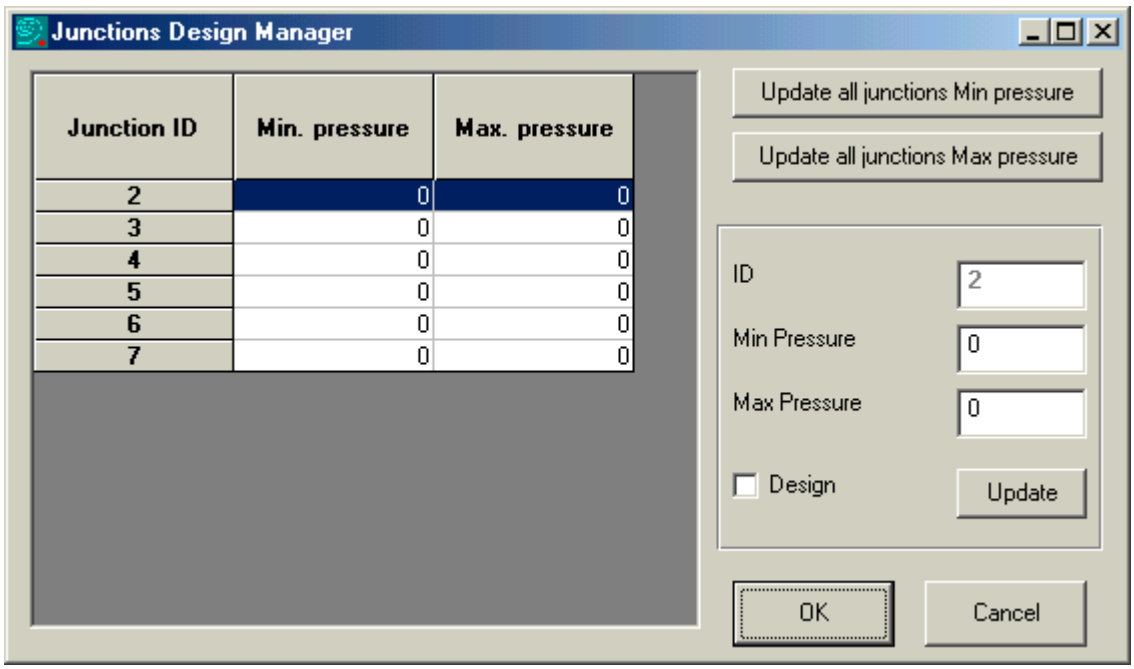


5. Click the "**Import…**" button and select the predefined file named "**Design_options.dat**" located in the "**Tutorial**" directory:



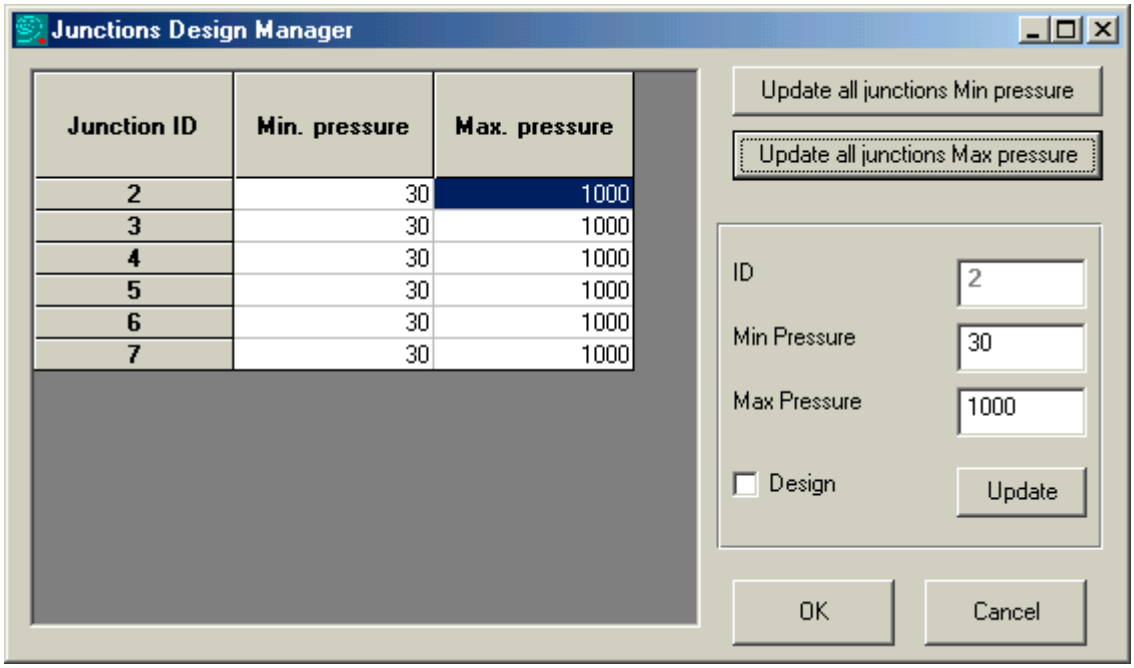
6. Click the "**OK**" button.

7. To enter the junctions options select "**Junctions…**" from the "**Design Option**" menu:

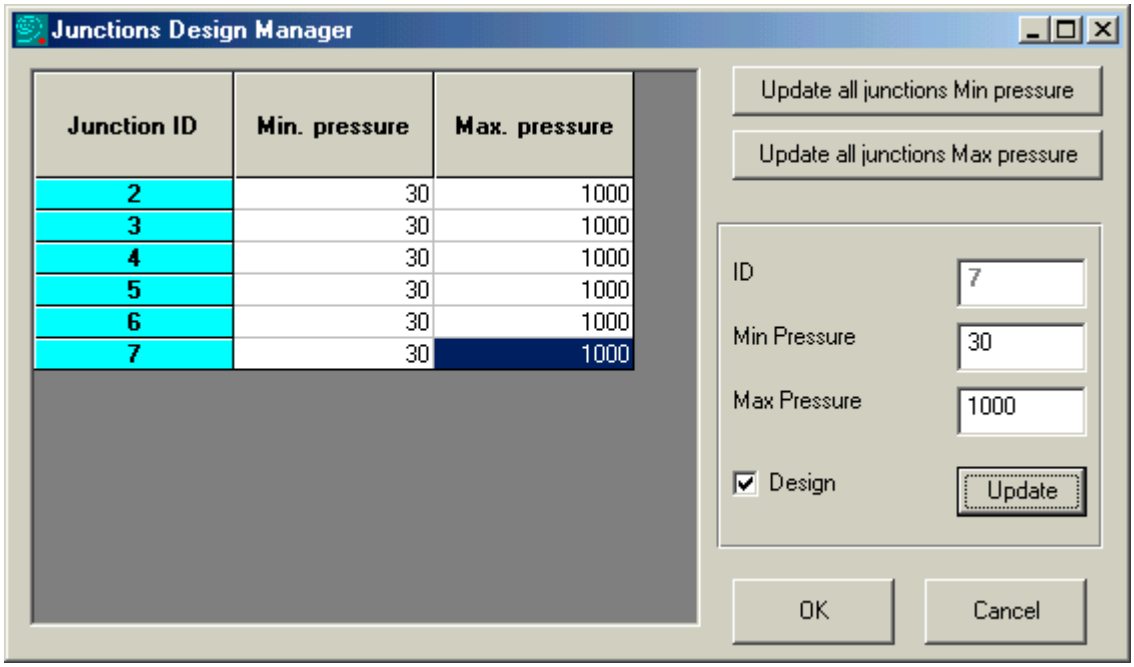


8. Since a minimal pressure of 30m is to be kept for junctions click the "**Update all junctions Min pressure**" button and enter 30.

9. Since there is no maximal pressure to be kept click the "**Update all junctions Max pressure**" button and a high value – 1000.

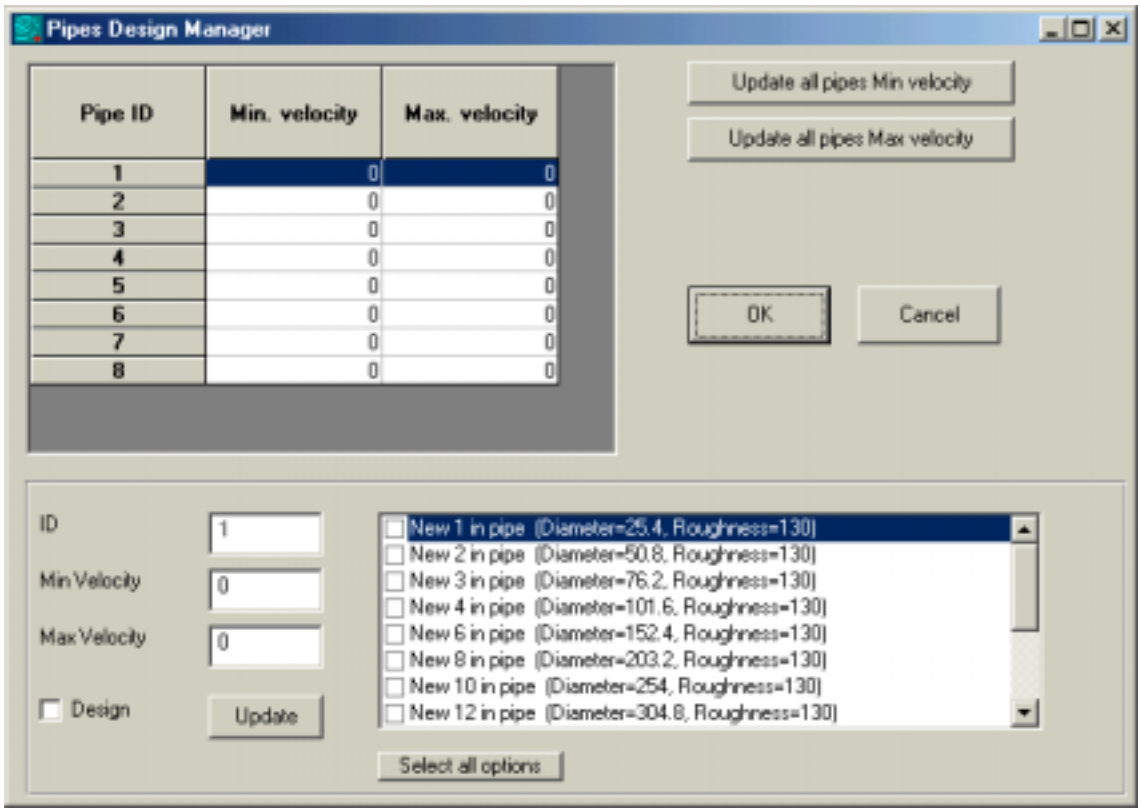


10. Now click each line in the table and check the "Design" check box for each junction. Make sure you click the "Update" button for each junction:



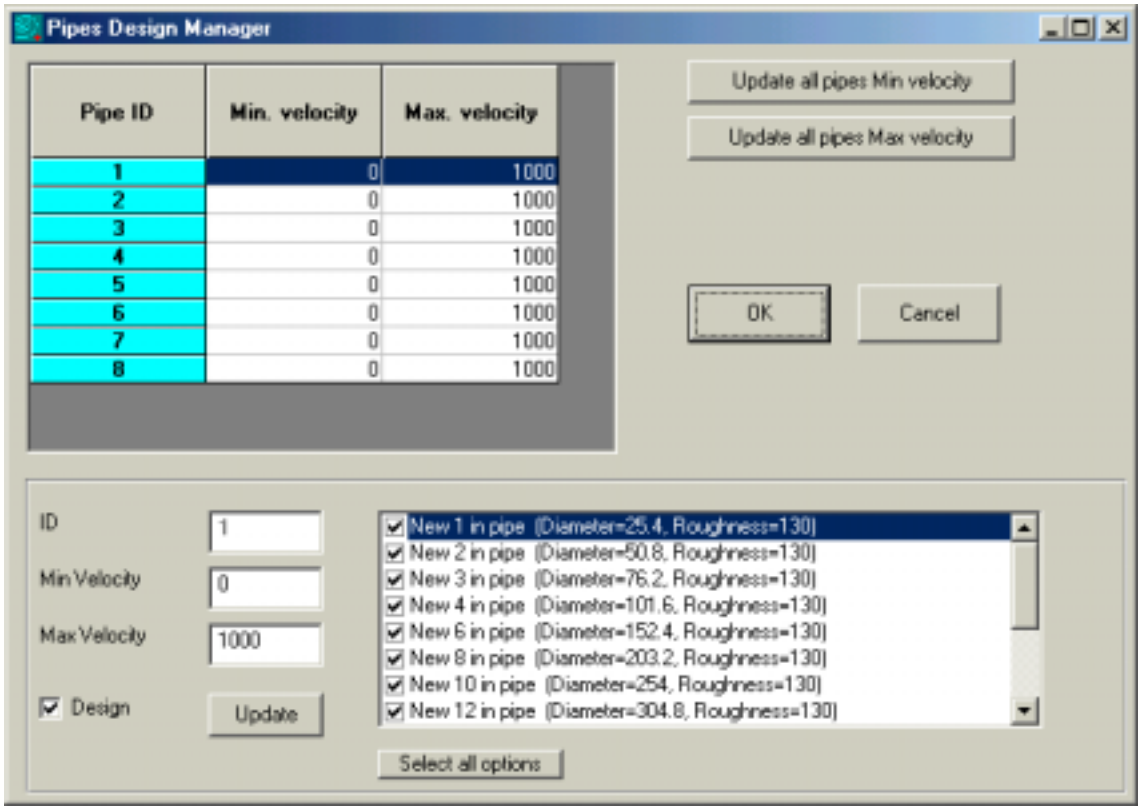
11. Click the "**OK**" button.

12. To enter the pipes options select "**pipes…**" from the "**Design Option**" menu:



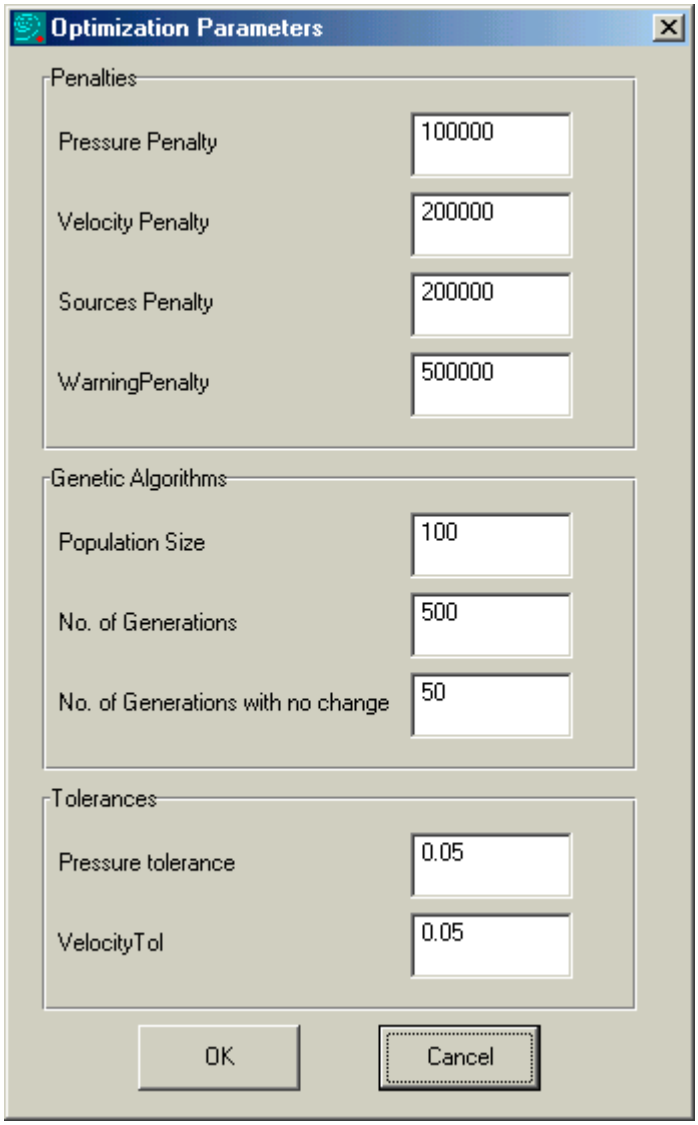
13. Click each row in the table and check the "**design**" check box and click the "**Select all options button**", then click the "**Update**" button.

14. Since there are no velocity limitation for the pipes click the "**Update all pipes Max velocity**" and enter a high value – 1000.



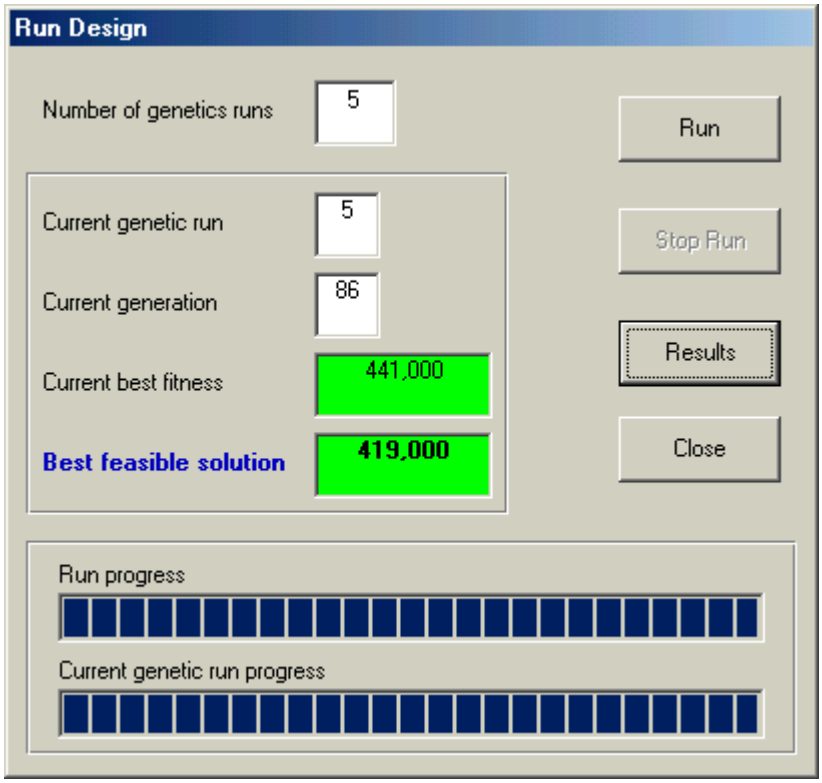
15. Click the "**OK**" button.

16. To enter the optimization options select "**Optimization Options**" from the "**Design Option**" menu and change the "**Pressure Penalty**" to 100,000. Click the "**OK**" button:



17. Before we run the design process save the project.

18. Enter the "**Run Design**" dialogue by selecting "**Run**" from the "**Design**" menu and click the "**Run**" button.



19. After the design process ends you may view the results by clicking the "**Results**" button.

Note: the best solution known for this problem with a single diameter for each pipe is 419,000 cost unit. optiDesigner reaches this solution almost every run!

How to use optiDesigner

The first step in using **optiDesigner** is to build the water distribution system (system) to be designed. The drawing and properties entry for the system is done with the EPANET hydraulic simulation software so make sure you have it installed properly.

System building

You begin building the system by starting EPANET and using its graphical user interface. For information on how to use the EPANET software please refer to the EPANET user manual that could be download from the EPANET web site at:

http://www.epa.gov/ORD/NRMRL/WSWRD/epanet.html

In general, you must build and enter legal data for all the system components: junctions, pipes, tanks, reservoirs and valves. For pipes to designed you must enter default legal data (like diameter = 10" and roughness = 100). Note that the length of the pipes being designed are known and should be entered correctly. Since **optiDesigner** can design only pipes, all other system components must be entered as they are. There are no limitations on the system; it can even be built as an extended period simulation (EPS).

After you build the system, test it by running a simulation within EPANET. To run a simulation, click the "**Run Analysis**" option in the "**Project**" menu within EPANET. If the run ends successfully you are fine and set to go. If the run ends with errors, you must correct the system and test it again. You may get some warnings when you run the simulation, that is OK but double check to see if you made no mistake.

Note: the simulation must end with no errors!

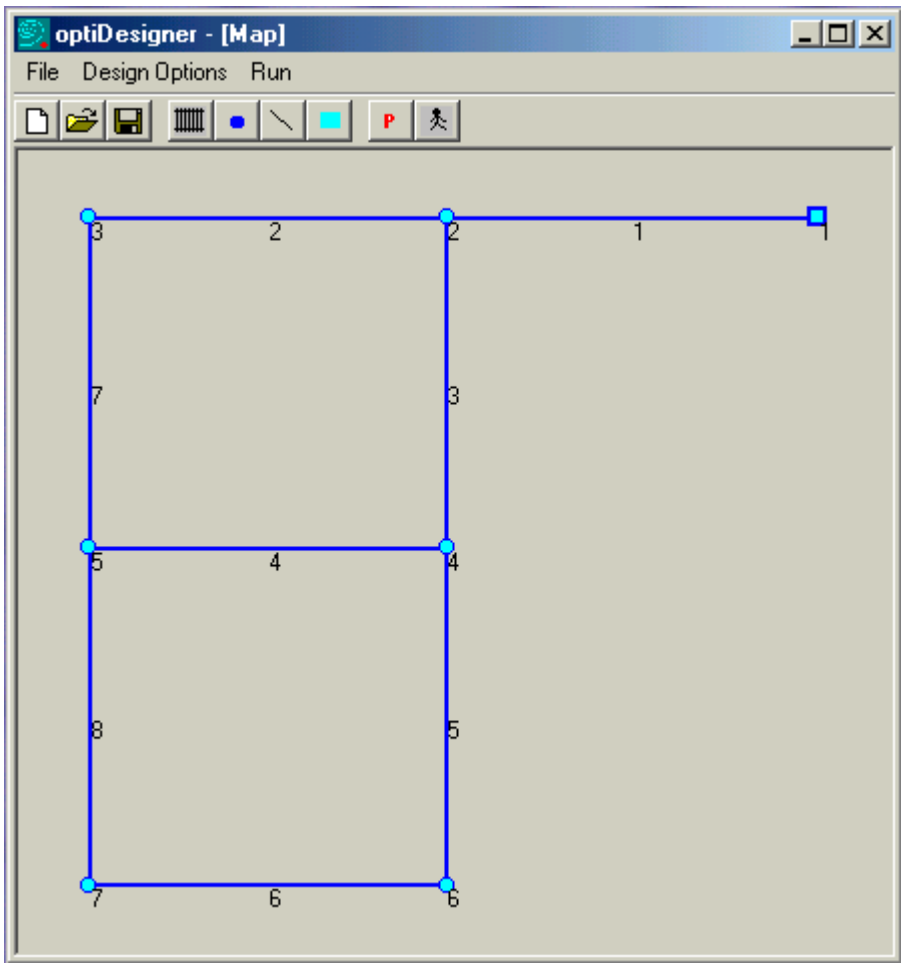
After the system has been tested with no errors it is time to export the system as an INP file. INP file is an ASCII file that holds all of the system information (it can viewed and edited with any text editor like **NotePad**). To export the system, select "**Export >**

Network" from the EPANET "**File**" menu. A save dialogue will pop up and you can select the file name and path for the INP file. Save the file in a directory where you want to run the design project.

Now it is time to quit the EPANET program and start the **optiDesigner** software.

Making a new project

After the system has been built and exported to an INP file you can start a new **optiDesigner** design project. From the "**File**" menu click "**New**". You will be prompt to select the INP file you have prepared. Select it and click "**Open**". If there are no error in the INP file the network will be shown on the screen:



Note: you can not edit or change the system from within optiDesigner. All changes must be done from EPANET.

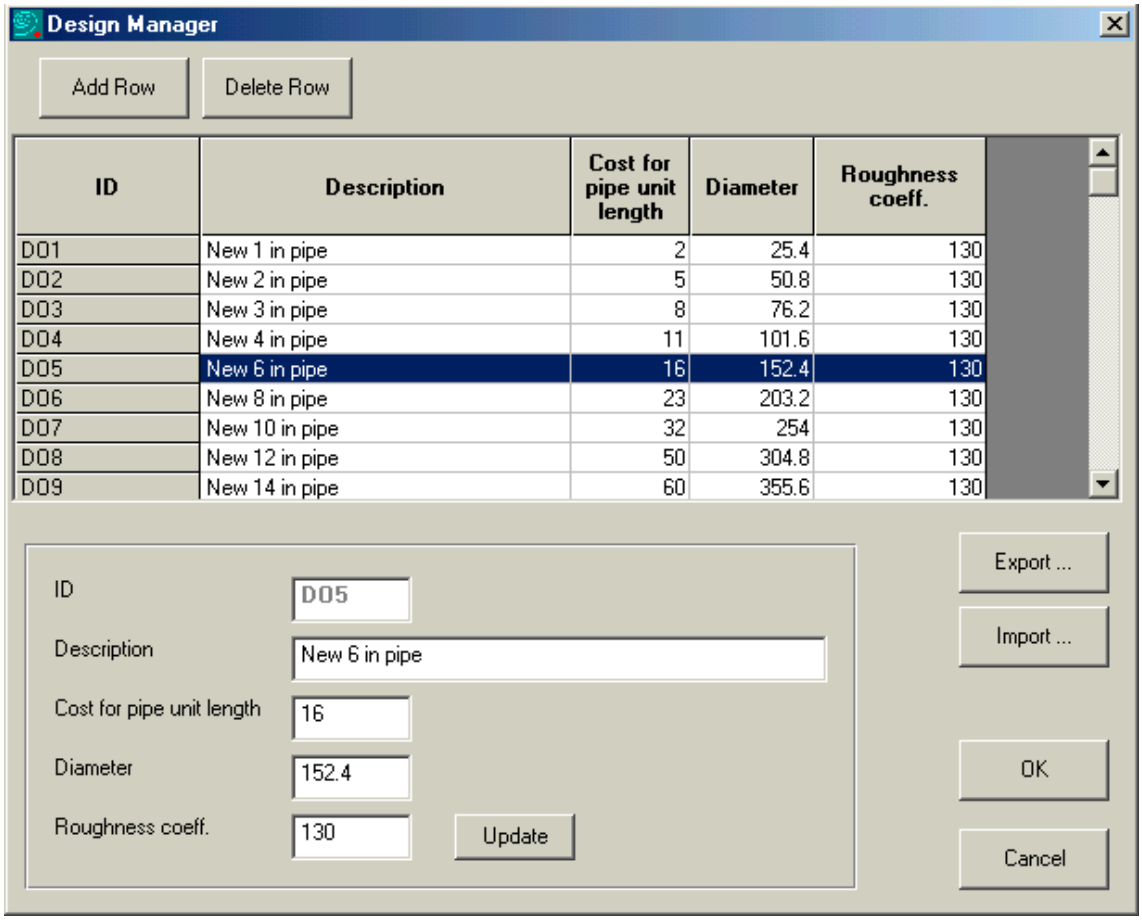
It is a good time now to save the design project by clicking the "**Save**" option from the "**File**" menu. You will be asked to give the design project a name and a path (the file will have the "OD" extension.

You must save the design project in the same directory you have placed the INP file. If you wish to move the design project to another directory you must copy the design project and the INP file to the same directory.

Note: the design project file (*.OD file) and the INP file must be in the same directory.

Entering the design options

The design options are a set of records that each represents pipe characteristics (diameter, roughness and cost). Later on we will chose the design options that are available for each pipe being designed. You may consider the design options as a kind of extended pipes catalogue. You enter the design option dialogue by clicking "**Design Manager**" from the "**Design Options**" menu:



If this is a new project, the design manager will be empty. The table consists of 5 columns:

- **ID** - an auto generated unique id;
- **Description** - a free text that describes the design options;
- **Cost per unit length** – unit cost of pipe;
- **Diameter** – pipes diameter;
- **Roughness** – pipes roughness.

To add a record click the "**Add Row**" button. To remove a record, first select it by clicking its row and then click the "**Delete Row**" button.

To enter data or change data, select a record by clicking on its row. The record will be highlighted and the record data will be shown in the text boxes on the bottom of the dialogue. After data entry\change click the "**Update**" button the update the record.

You can export the data you entered to a file in order to use it in another design project by clicking the "**Export**" button. To import a saved data set, click the "**Import**" button.

After finishing editing the design options click the "**OK**" button or click the "**Cancel**" button to discard any changes made.

Note: you must enter at least two design options and no field can be left empty.

Note: if you enter a zero value for the diameter parameter the design option will be a closed pipe!

Selecting pipes design options

In this dialogue you assign design options to pipes you want to design and their velocity constraints. To enter the pipes design manager click "**Pipes**" from the "**Design Options**" menu. The manager holds a table with all of the systems pipes. To select a record in the table click on the records row. The record data will be shown in the text boxes on the bottom of the dialogue. At this point you can edit \change the record data. If you want to select a pipe for design, check the "**Design**" box. To select the design options for the pipe, check all relevant options in the list. Click the "**Update**" button to except the changes. If you selected the pipe to be designed the "**ID**" field will be painted in cyan. To change the minimum or maximum velocities for all pipes use the "**Update all pipes Min velocity**" and "**Update all pipes Max velocity**" buttons.

When you are done editing click the "**OK**" button or the "**Cancel**" button to discard all changes.

Note: pipes that are not selected for design will keep their properties that you used when you built the system with EPANET.

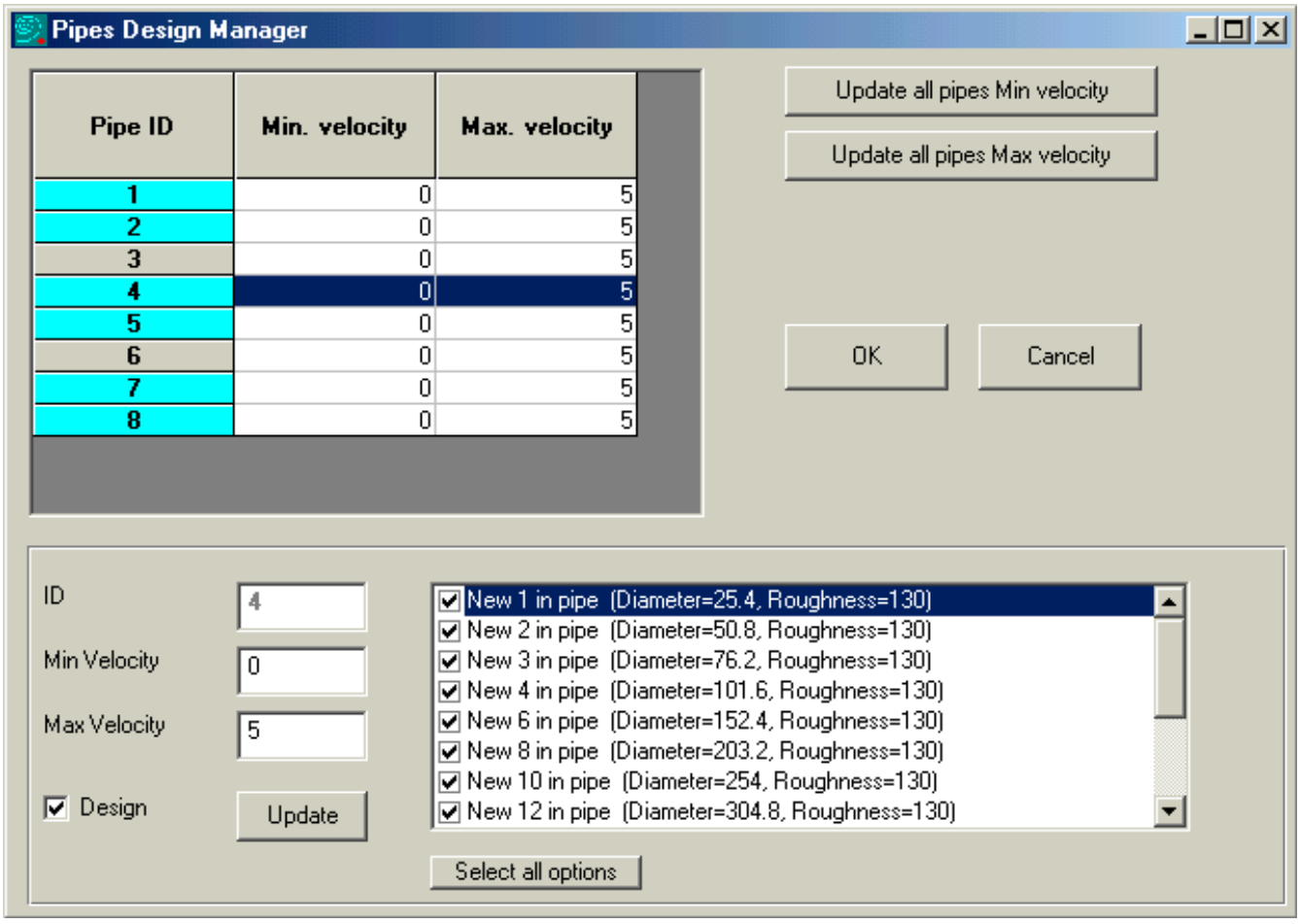
Note: the velocity units used in this dialogue are the ones that you used when you

built the system with EPANET.

Note: Each pipe you want to design must have two or more design options associated with him.

Note: you must select at least one pipe to be designed.

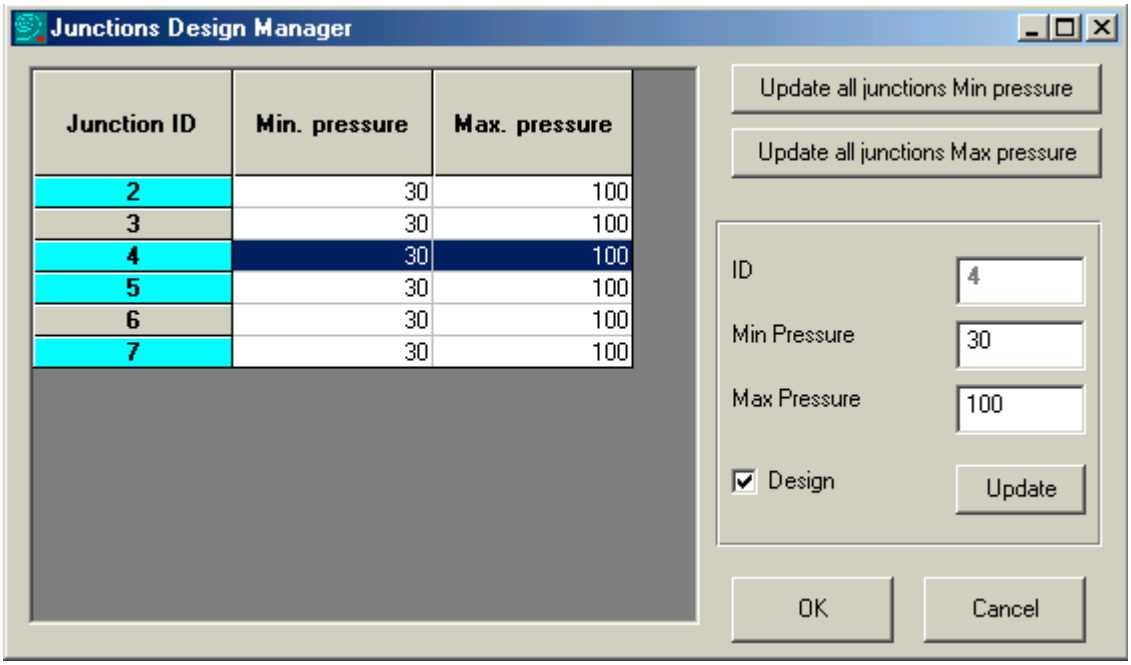
Note: if you want to select a pipe for design but don't want it to have a minimum or maximum velocity constraint, enter 0 for the minimum velocity and a large number for the maximum velocity (999999).



Entering junctions constraints

With the "**Junctions Design Manager**" you can specify which junctions in the system have pressure constraints? Each junction in the system can have a minimum and maximum pressure constraint. To open the dialogue click "**Junctions**" from the

"**Design Manager**" menu:



The table shows a list of all junctions in the system and their minimum and maximum pressures allowed. To select a record, click on the record row. The record data will be shown in the text boxes on the left. At this point you may edit the data. If you want that the junction you have selected will "be designed" (have pressure constraints) check the "**Design**" box. To update the data click the "**Update**" button before continuing with the next junction. If you selected the junction to be designed the "**ID**" field will be painted in cyan. To change the minimum or maximum pressures for all junctions use the "**Update all junctions Min pressure**" and "**Update all junctions Max pressure**" buttons.

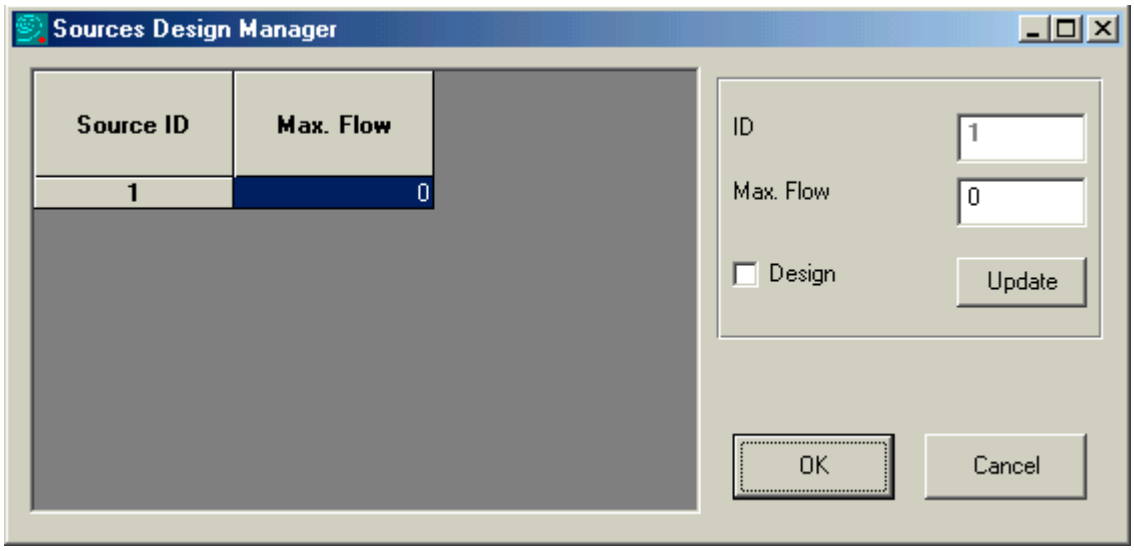
When you are done editing click the "**OK**" button or the "**Cancel**" button to discard all changes.

Note: the pressure units used in this dialogue are the ones that you used when you built the system with EPANET.

Note: if you want to select a junction for design but don't want it to have a minimum or maximum pressure constraint, enter a large negative number for the minimum pressure (-999999) and a large number for the maximum pressure (999999).

Entering sources constraints

In the "Sources design Manager" you may specify whether one or more of the system sources have a flow constraint. This option may be used, for example, when you have a water well with limited pumping equipment available. A source of the system is any reservoir defined in the EPANET software (by the way, a reservoir is a good way to simulate a well). Each source in the system can have a maximum flow constraint (discharge). To open the dialogue click "**Sources**" from the "**Design Manager**" menu:



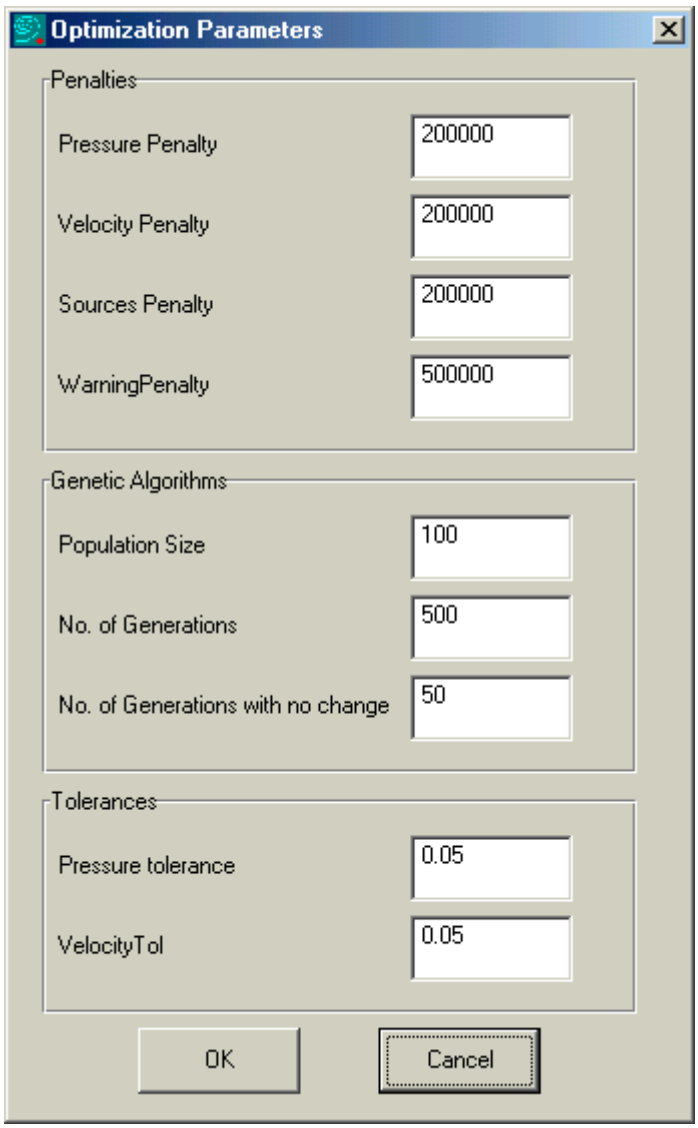
The table shows a list of all sources to the system and their maximum flow allowed. To select a record, click on the record row. The record data will be shown in the text boxes on the left. At this point you may edit the data. If you want that the source you have selected will "be designed" (have flow constraints) check the "**Design**" box. To update the data click the "**Update**" button before continuing with the next source. If you selected the source to be designed the "**ID**" field will be painted in cyan.

When you are done editing click the "**OK**" button or the "**Cancel**" button to discard all changes.

Note: the flow units used in this dialogue are the ones that you used when you built the system with EPANET.

Optimization parameters

There are nine parameters that control the optimization process of optiDesigner. To edit the optimization parameters select the "**Optimization Options**" from the "**Design Options**" menu:



There are three groups of parameters in this dialogue box:

Penalties

The penalties are the most important parameters in the optimization process. The objective function of the process is minimization of the total pipe cost. Of course, it is possible to lower the cost if the constraints are not satisfied (pressures, velocities and sources flows) so the algorithm must take the violation of these constraints into account.

The way to do that is to introduce a penalty upon a constraint violation. There is a penalty for each kind of constraint:

Pressure penalty – the penalty for each unit of pressure constraint violation. The default penalty is 200,000.

Velocity penalty – the penalty for each unit of velocity constraint violation. The default penalty is 200,000.

Sources penalty – the penalty for each unit of flow constraint violation. The default penalty is 200,000.

Warning penalty – a penalty that is introduced when the hydraulic solver reports a warning. The default penalty is 500,000.

Note: how to set the penalties is the million-dollar question. There is no simple answer for it. In most cases it will take some time with trail and error process to get the penalties that produces the best results. Penalties that are too small won't effect the solution and there will be constrains violations. On the other hand, large penalties will have the opposite effect. The solution may be feasible but the cost will be high. The penalties would "chock" the algorithm. So what to do? Start with a low set of penalties that probably won't give you a feasible solution. Then increase the penalties until you get a feasible solution. Try changing one penalty at a time to see how it effects the solution.

Genetic algorithms

The next three parameters are genetic algorithms related (see the genetic algorithm chapter):

Population size – the number of individuals in the genetic population. The default value is 500. This value must be an even number greater then 2.

Number of generations – the maximum number of generation the population is allowed to evolve. The default value is 500

Number of generations with no change – the number of generation the population is allowed to evolve with no change in the best fitness (the minimal design cost). The default value is 50.

Tolerances

The pressure and the velocity constraints are many times very tight. It is best to have a small tolerance with these constraints:

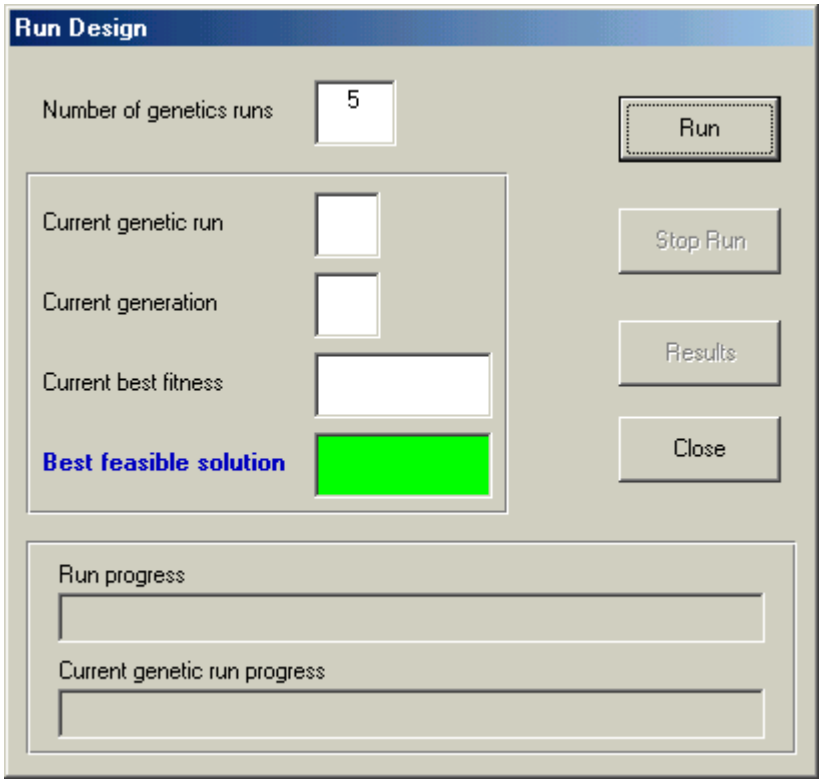
Pressure tolerance – the tolerance for the pressure constrains. The default value is 0.05.

Velocity tolerance – the tolerance for the velocity constrains. The default value is 0.05.

Running a design simulation

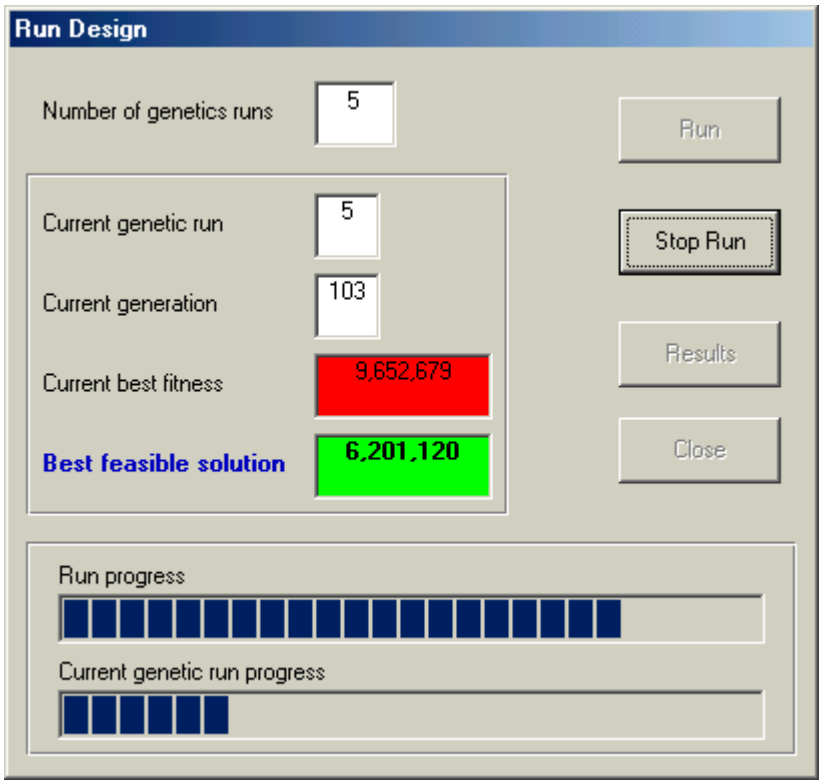
Once the problem had been defined it is time to run a design simulation. To open the "**Run Design**" dialogue, select "**Design**" from the "**Run**" menu. The only parameter to be set before the "**Run**" button should be clicked is the "number of genetics runs". This parameter controls the number of genetics design processes that will be made. Since the genetic algorithm doesn't guarantee a global optimum, several runs should be made in order to get a good solution. The default value is 5 runs. Once this parameter is set you can start the design process. In the main frame of the dialogue there are four fields:

- **Current genetic run** – the current run out of the "number of genetics runs".
- **Current generation** – the current genetic generation within the current genetic run.
- **Current best fitness** – the best fitness within the current genetic run. If the current best fitness is feasible then the background of the text box will be painted green. If not, the background will be painted red.
- **Best feasible solution** – the best overall feasible solution reached.



While the design process is on, the progress bars on the bottom of the dialogue show its progress.

The run can be stopped by clicking the "**Stop Run**" button.

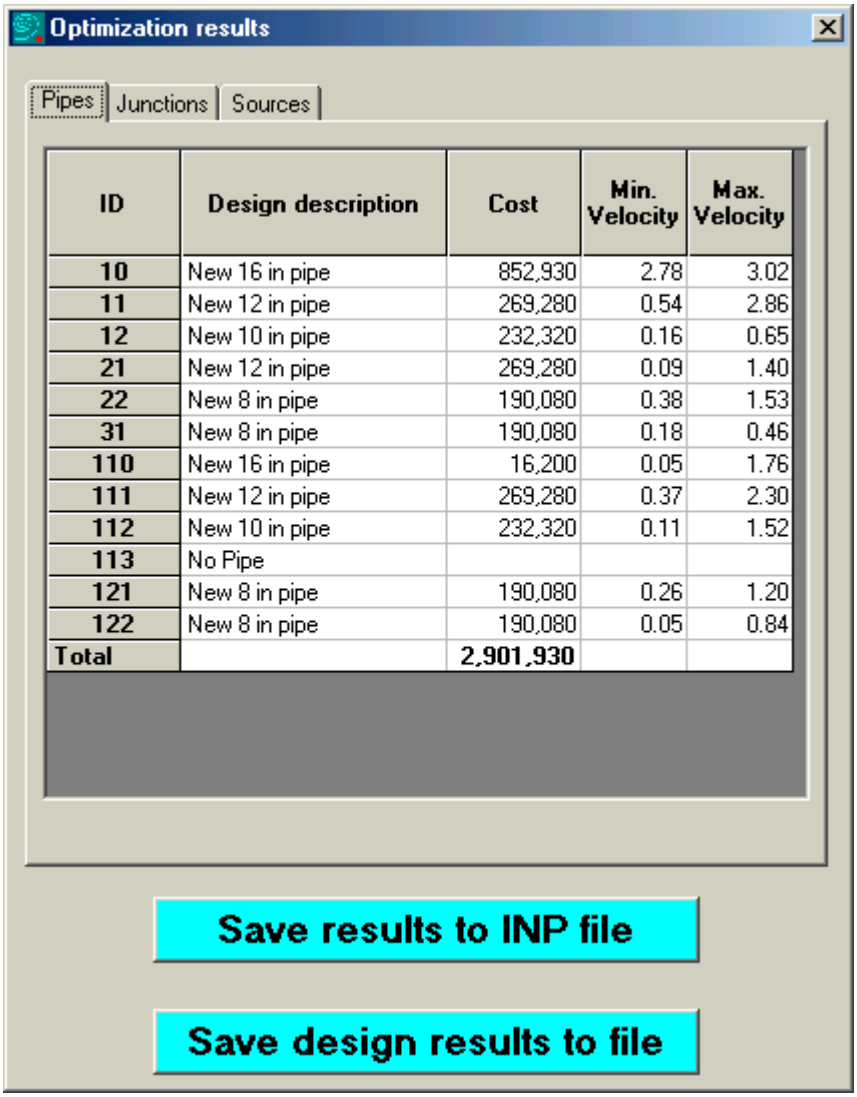


At the end of the design process you will be prompt whether a feasible solution was found or not.

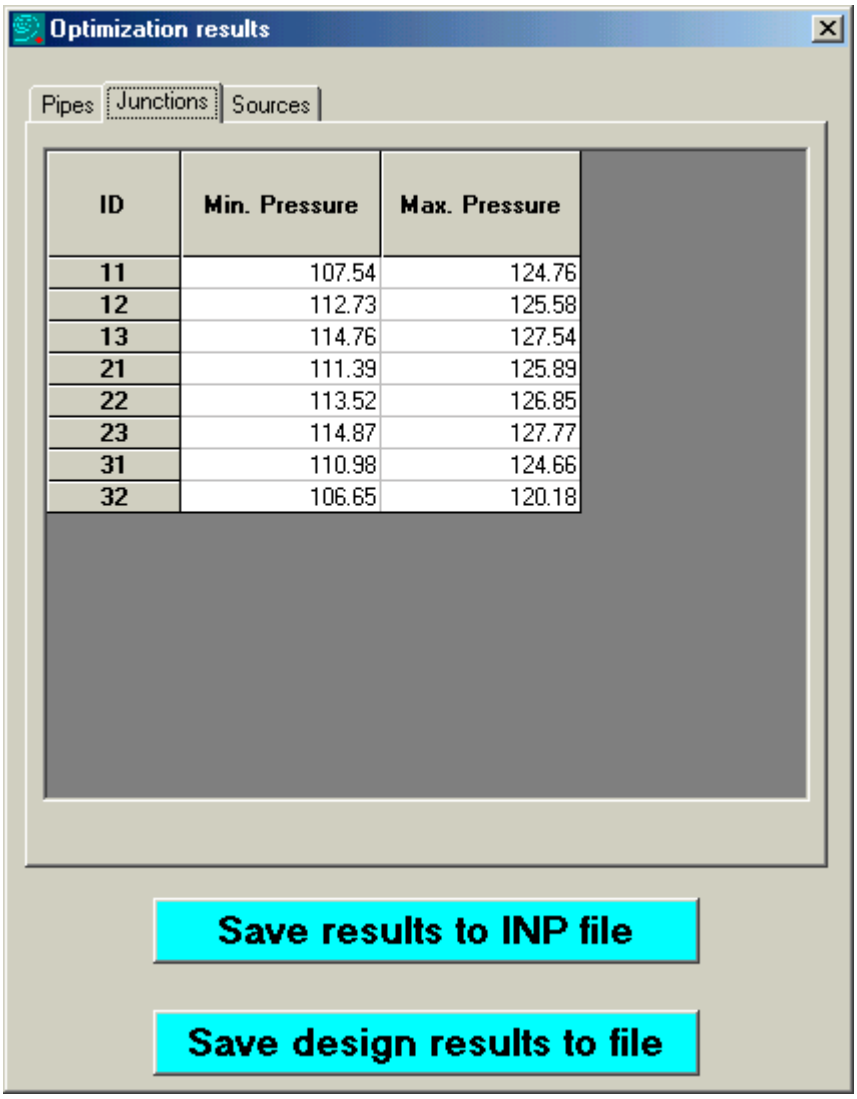
Viewing results

Once the design process comes to end and a feasible solution has been found, you can view the design results by clicking the "**Results**" button in the "**Run Design**" dialogue, or select "**Results**" from the "**Run**" menu.

The dialogue shows the results for the pipes, junctions and sources.



ID	Design description	Cost	Min. Velocity	Max. Velocity
10	New 16 in pipe	852,930	2.78	3.02
11	New 12 in pipe	269,280	0.54	2.86
12	New 10 in pipe	232,320	0.16	0.65
21	New 12 in pipe	269,280	0.09	1.40
22	New 8 in pipe	190,080	0.38	1.53
31	New 8 in pipe	190,080	0.18	0.46
110	New 16 in pipe	16,200	0.05	1.76
111	New 12 in pipe	269,280	0.37	2.30
112	New 10 in pipe	232,320	0.11	1.52
113	No Pipe			
121	New 8 in pipe	190,080	0.26	1.20
122	New 8 in pipe	190,080	0.05	0.84
Total		2,901,930		



The results can be saved in to ways:

- **Save results to INP file** – the results are saved to an INP file that can be opened by the EPANET software.
- **Save design results to file** – the content of the results dialogue are saved to an ASCII file that can be viewed by any text editor or can be imported to any spreadsheet like Microsoft Excel.

Data files

Each design project consist of two files:

- **INP file** – the EPANET program created the INP file. After you build the system with EPANET you have to export it to an INP file.
- **OD file** – this file holds the design data. It is build by optiDesigner and **must** be saved in the same directory as the INP file!

If you want to move the project to a different directory you have to copy\move both files to the new location.

Registration Utility

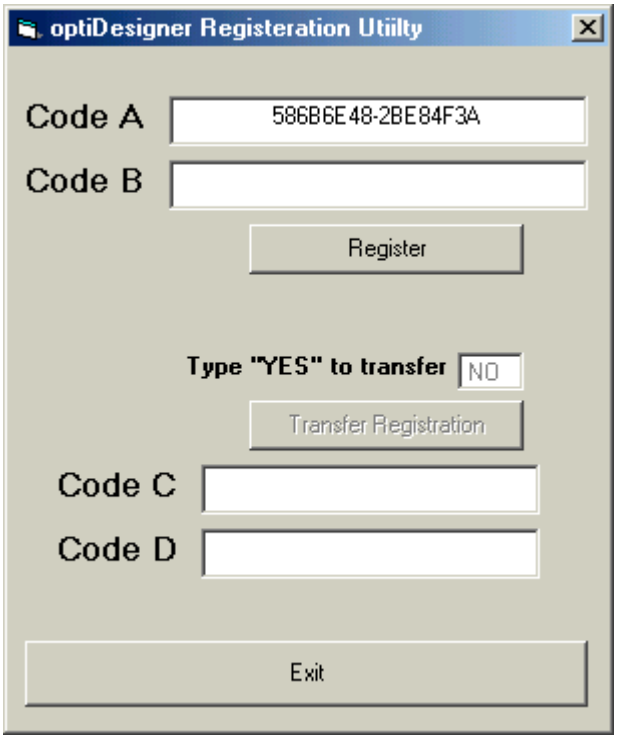
As explained in the license chapter, the evaluation copy of optiDesigner can be used for only 30 days. After that, if the user would like to keep using optiDesigner, he should register the software.

Registration

Registering optiDesigner is easy to do at:

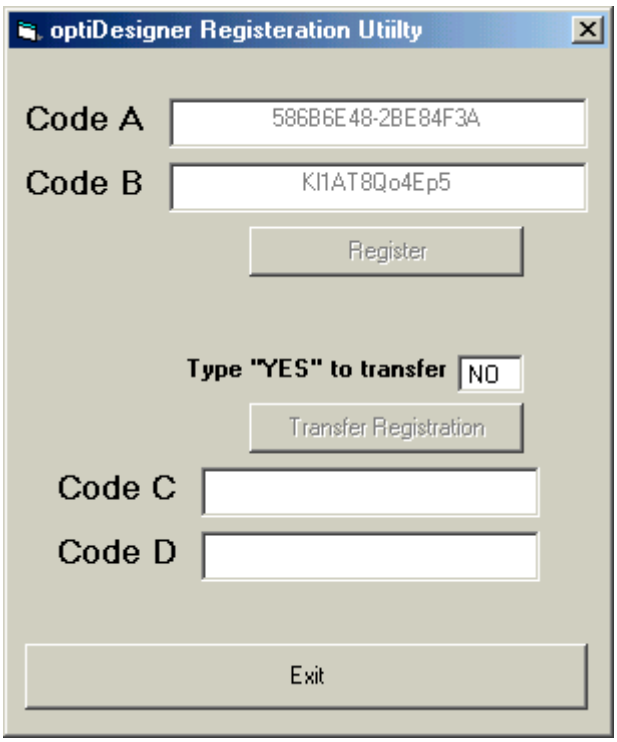
http://www.optiwater.com/optidesigner/register.html

Before you begin the registration process run the registration utility that is located in the optiDesigner program group (the "REGISTER.EXE" file is located in the same directory you installed optiDesigner).



The utility will provide you a code called "**Code A**". You will be asked to provide this code during the registration process. After your registration will be approved you will receive a confirmation code "**Codes B**" which you will have to enter in the registration utility and click the "**Register**" button.

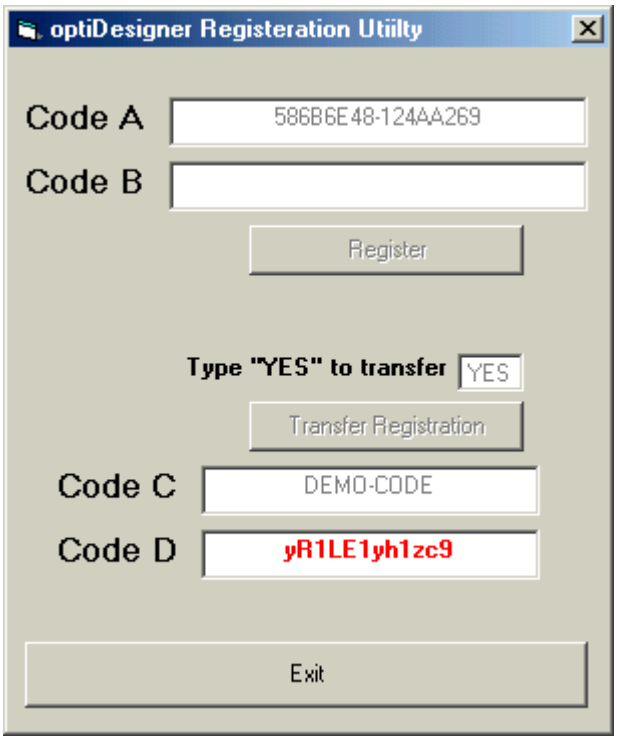
That is it!



Transferring the license

If you would like to transfer the license to a different computer you should follow these steps:

1. Install optiDesigner on the target computer.
2. Run the registration utility on the target computer and copy the first registration code – "**Code A**".
3. Run the registration utility on the source computer (the computer where the optiDesigner is registered) and type the word "**YES**" in the transfer text box.
4. You will be asked to enter the code you copied from the target computer. It will be entered as "**Code C**".
5. A new code will be shown in the "**Code D**" text box. Use this code as "**Code B**" for the target computer.



After you transfer the registration to the target computer optiDesigner will not work on the source computer.

Contacts and Registration

Registration

Registering your own copy of optiDesigner is easy to do at:

http://www.optiwater.com/optidesigner/register.html

You will be given all the payment options:

- Secure online credit card payment
- Purchase Orders
- Mail orders

Full details are found on the site.

Contacts

The best place for information is the optiDesigner web site at:

http://www.optiwater.com/

Or you can mail me at: support@optiwater.com with requests for information, technical assistance or bug reports.